

# PATENT SPECIFICATION

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## COMPLETE SPECIFICATION

### Reduction of Iron Oxide Ores

We, J.C.I. METAL HOLDINGS (PROPRIETARY) LIMITED, a Company organized under the Laws of the Republic of South Africa, of Consolidated Building, Corner Fox and Harrison Streets, Johannesburg, Republic of South Africa, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:

This invention relates to a process and apparatus for reducing iron oxide ores to produce metallic iron. In particular, the invention may be used for the direct manufacture of steel without a separate conversion operation.

It is well known that iron oxide ores can be reduced in the solid state to produce metallic iron. This is the basis of most of the so-called direct reduction processes. A solid carbonaceous reducing agent such as coke, anthracite or bituminous coal is often the most convenient reducing agent. It is also well known that the intimacy of contact between the ore and the reducing agent as well as the temperature of the reduction have a pronounced effect on the rate and the completeness of the reduction.

The present applicants' British Specification No. 1,087,306 describes a process for reducing iron oxides to produce metallic iron which comprises mixing finely divided iron ore with finely divided medium to strongly coking coal; forming the mixture into pellets; heating the pellets in a shaft kiln at a temperature at which the coal carbonises to coke and the iron ore is partially reduced, a flow of pellets being maintained through the shaft by supplying pellets at the top of the column of pellets in the shaft and discharging them over a discharging edge at the base of the shaft, the

column adjacent to the discharging edge presenting a surface exposed to heating gases which pass up through the column; and passing the heated pellets discharged over the said edge out of contact with air to a furnace containing a turbulent melt of iron and slag wherein the final reduction of ore to metal is completed. In that process a substantial proportion (e.g. 50%, or more) of the iron oxide is reduced in the shaft kiln.

It may be found in that process, and in other processes in which pellets of finely divided iron ore and carbonaceous reducing agent are heated to effect a preliminary partial reduction in the solid state, that some adhesion of the pellets to one another may occur during this operation, and one solution to this problem is to mix an excess of relatively finely divided carbonaceous material with the charge of pellets. This has the effect of reducing the areas of contact between individual pellets. However, it has the disadvantage that there is an excess of carbon present in the resulting iron so that a separate conversion step is required in order to form steel.

According to the present invention, granular carbonaceous material smaller in size than the pellets is mixed with a charge of pellets in sufficient quantity to eliminate or diminish adhesion between the pellets, the mixture is heated in a shaft kiln so that the iron oxide in the ore is at least 90% reduced by carbon, the material discharged over a discharge edge at the base of the shaft is screened, out of contact with air, to separate granular carbonaceous material from the reduced pellets before the latter are admitted to the final steel melting furnace, and the screened carbonaceous material is cooled, still out of contact with air, to a temperature below that at

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which combustion would be sustained and is recycled to the pellet charge.

By screening out the surplus relatively finely divided carbonaceous material, the charge of reduced pellets for the final reduction furnace need not contain an excess of carbon, so that steel can be produced directly in the furnace without a separate conversion operation.

10 Some or all of the hot gases from the top of the column in the shaft kiln may be passed through a drying oven for hardening and strengthening the pellets on their way to the shaft kiln. If a conveying drying oven is used  
 11 this can be inclined so as to serve also as a means of elevating the pellets, e.g. into a mixing and feeding hopper which feeds the mixture into the shaft kiln.

The invention may be performed in various ways and a specific embodiment will now be described by way of example with reference to the accompanying drawing, which is a diagram of a plant in which the said embodiment is carried out. Referring to the drawing, a vertical shaft kiln 10 is provided the lower end of which communicates with a combustion chamber 11 equipped with a burner 12 for burning a fuel such as gas or oil to provide hot gases for heating the charge 13 in the shaft. These hot gases may consist essentially of carbon dioxide and monoxide, water vapour and hydrogen. There is a feed hopper 14 communicating with the shaft through which can be admitted a charge consisting of a mixture of dried pellets, say  $3/8"$  to  $3/4"$  in diameter, and granular carbonaceous material such as coke breeze say  $1/8"$  to  $1/4"$  in size. The floor 15 at the bottom of the shaft has a discharging edge 16, the charge 13 resting on the floor and forming a sloping firing surface 17 at its natural angle of repose above the discharging edge 16. The charge is continuously discharged over the discharging edge in the way described in relation to Figure 3 of the aforementioned British Patent Specification No. 1,087,306. However, any other suitable form of discharging edge, mobile or stationary, could be used. The sloping firing surface 17 of the charge is exposed to the combustion chamber 11, and the hot combustion gases pass in through this surface and up through the shaft 10, thereby heating the charge 13 to a temperature which may be in the range 1050 to 1350°C at the firing surface 17.

Preferably the air supply to the burner 12 is restricted so that the combustion of the fuel gas or oil is incomplete, to diminish the carbon dioxide and water vapour contents of the combustion gases as compared with what would be produced by complete combustion of the fuel from the burner. This reduces the consumption of the coke breeze which is added to the charge in the hopper 11. The temperature in the combustion cham-

ber 11 is maintained in excess of 900°C. In the shaft 10, reduction of the carbon dioxide and water vapour will occur so that the gases passing up the shaft will consist of more carbon monoxide and hydrogen than in the combustion zone. If desired, air may be admitted through inlets 18 about half way up the charge in the shaft to burn some or all the carbon monoxide and hydrogen, thereby providing additional heating of the charge.

From the shaft above the upper surface 19 of the charge some or all of the rising hot gases are extracted via a conduit 20 and pass through a conveyor type drying oven 21 in the direction of the full line arrows. This oven is inclined upwardly and contains an endless belt conveyor 22 which moves in the direction of the broken line arrows. This conveyor receives at its lower end 23 moist pellets from a hopper 24 and carries them up in counterflow to the hot gases, whereby the pellets are dried and the gases are cooled. The pellets are discharged from the upper end of the conveyor 22 into the shaft hopper 14, while the now cooled gases are discharged from the lower end of the drying oven, for instance by means of an extractor fan 25.

The pellets can be formed from a mixture of finely divided iron ore and finely divided weakly to strongly coking coal or other carbonaceous material.

In the shaft hopper 14 these pellets are mixed with finely divided coke breeze, some or all of which has been recycled through a line 26 in a manner to be described. The mixing proportions are such that at the firing surface 17, where the pellets are somewhat sticky, they are prevented from contact with one another by intervening particles of coke breeze. Lime or limestone may be added to the charge to flux the gauge in the ore and in the ash when the pellets are subsequently melted. The gangue is usually high in silica and often contains alumina, which constituents will form a slag when the pellets are melted in the furnace 28 referred to below. Limestone or dolomite can also be added to the charge to absorb sulphur which is generally present in carbonaceous material.

The charge of partially reduced pellets and coke breeze which has not been consumed in the shaft is discharged over the discharging edge 16 into the bottom of the combustion chamber 11, which comprise a downwardly sloping screen 29. The screen apertures are large enough to allow the coke breeze particles to fall through but are considerably smaller than the pellets, which roll down over the screen into an insulated feeding hopper 30 from which they are fed whilst still hot in to the furnace 28, which may be a conventional electric arc smelting furnace.

The coke breeze which has passed through the screen 29 enters a cooler 31 where it is cooled, as by water sprays 32, to reduce its 130

temperature from the 1000°C temperature of the combustion chamber 11 to about 300°C or less. At the latter temperature the coke breeze will not sustain combustion in the presence of air and may therefore be discharged from the cooler 31 into normal atmospheric conditions, whereupon it can be recycled by any suitable means (here indicated by the line 26) for mixture with fresh dry pellets in the shaft hopper 14.

The cooled coke breeze can also be passed over a magnetic separator 33 to remove any iron which may result from broken pellets.

The proportions of iron ore and coal used in making the pellets are preferably controlled so that the amount of carbon is sufficient for reducing at least 90% of the iron oxide to the metallic state but is not in large stoichiometric excess. Even taking into account the amount of additional carbon that may enter the electric arc furnace 28 in the form of particles of coke breeze adhering to the pellets, the amount of carbon present may be such that steel will be formed in the electric furnace 28.

In the initial formation of the pellets a binding agent may be used to increase the strength of the pellets.

**WHAT WE CLAIM IS:—**

- 30 1. A process for reducing iron oxides to produce metallic iron or steel which comprises mixing finely divided iron ore with finely divided carbonaceous reducing agent; forming the mixture into pellets; mixing with the pellets granular carbonaceous material smaller in size than the pellets, in sufficient quantity to eliminate or diminish subsequent adhesion between the pellets; heating the mixture in a shaft kiln so that the iron oxide in the ore is at least 90%, reduced by carbon, a flow of the mixture being maintained through the shaft by supplying mixture at the top of the column of mixture in the shaft and discharging mixture over a discharge edge at the base of the shaft, the column adjacent the discharge edge presenting a surface exposed to heating gases which pass up through the column; screening the mixture discharged over the discharge edge, out of contact with air, to separate granular carbonaceous material from the reduced pellets; passing the hot separated pellets, still out of contact with air, to a furnace containing a melt of steel wherein the reduced pellets are melted to steel and slag; cooling the separated granular carbonaceous material, still out of contact with air, to a temperature below that at which combustion would be sustained; and recycling the cooled, granular carbonaceous material to the pellet charge. 45
- 5 2. A process as claimed in Claim 1 in which at least some of the hot gases from the top of the column of mixture in the shaft kiln are passed through a drying oven for hardening and strengthening the pellets on their way to the shaft kiln. 50
- 10 3. A process as claimed in Claim 2 in which an inclined conveying drying oven is employed which serves also to elevate the pellets. 55
- 15 4. A process as claimed in any of the preceding claims in which the proportions of iron ore and coal used in making the pellets are controlled so that the amount of carbon present in the reduced material entering the furnace is such that steel is formed in the furnace. 60
- 20 5. A process for reducing iron oxides to produce metallic iron or steel, substantially as described with reference to the accompanying diagrammatic drawing. 65
- 25 6. Iron and steel which have been produced by processes as claimed in any of the preceding claims. 70
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COMPLETE SPECIFICATION

1 SHEET

*This drawing is a reproduction of  
the Original on a reduced scale*

